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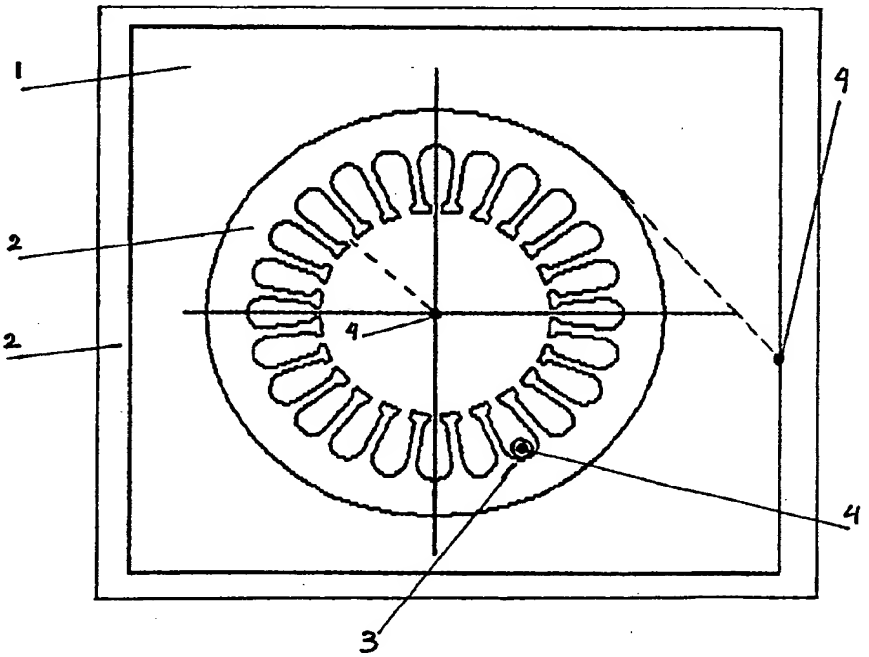
(54) Title: CUTTING CORES FROM AMORPHOUS MATERIAL BY NON CORROSIVE LIQUIDS AND ABRASIVES



(57) Abstract

Production of cores for rotating electric machines, from non crystal amorphous materials, by cutting using non corrosive cutting liquid and abrasive powder, and starting cutting on an edge of the material, to prevent delamination.

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CUTTING CORES FROM AMORPHOUS MATERIAL BY NON CORROSIVE LIQUIDS AND ABRASIVES.

The invention regards methods of production an electric rotating machines from non crystal (amorphous) magnetic materials.

A primary object of the invention regards lamination and cutting of magnetic material to parts with profiles required for production magnetic circuits of rotating electric machines and using invented methods to existing and to new construction of electric machines.

Amorphous magnetic materials, also known as non crystal magnetic materials or magnetic glasses, are currently produced by Allied Corporation in US and Japan, by Goodfellow in United Kingdom and Vacuumschmelze GMBH in Germany.
They are made as a very thin (0.017 to 0.05mm), one side oxidised ribbon, according to the United States Patent No. 4.298.382.
Their core losses are ten times lower than conventional silicon steel and they are the best for application to cores of electric machines (motors, generators and transformers) [2].
These materials are generally known as Metglas.

At the ribbon stage amorphous materials are not suitable to produce stacked core of transformers and electric rotating machines.
Ribbons of amorphous materials are compacted to wound cores or to strips.
They could be hot compacted according to US Patent No. 4.529.458 by the method of pressure and thermal diffusion.
Hot compacted strips are known as Powercore strips.
The Powercore strips are very thin (0.2mm) and extremely brittle. They are cut on 90 and 45 degree only. [4]

Due to reduction of eddy current, process of production standard electric machines from silicon steel requires, assembling the cores from thin (0.3 to 0.5mm) singular cut strips.

Such technology is not required to produce cores from amorphous magnetic materials. Amorphous materials are produced as very thin 0.017 to

0.035mm ribbon with resistivity from 123 to 142 (u-ohm-cm), therefore eddy current in singular ribbon are reduced almost to zero.
Insulations of a adhesive material and of the oxidise of the ribbon prevent to spread eddy current in laminated strips.

Therefore it is more convenient to laminate much thicker stacks of amorphous magnetic material and then cut them on required profiles.

Development of alternative easier and cheaper method of bonding amorphous ribbons was completed by the inventor and disclosed in this invention.
Ribbons were bonded by special adhesive material, Ardalite F with Hardener 905 made by Ciba Geigy were found as the best materials for lamination these ribbons to magnetic cores of electric rotating machines. Glue is spread between ribbons of the compacted material. Total stack is compressed and baked below recrystallisation temperature.
Cores are very rigid and brittles with lamination factor higher than 0.825. They are easy for handling and assembling.

Methods of assembling standard and amorphous cores of 0.5kw asynchronous electric rotating machines are presented on figure 1, (1) - silicon steel core, 180 pieces, (2) - amorphous core 9 pieces.

Amorphous materials are extremely hard (800 to 1100 in Vickers Scale) and it was a main reason which prevented them from using it as a magnetic circuits in electric rotating machines.
Standard cutting methods, for example the guillotine or blank die are not suitable for cutting amorphous materials. The material is mechanically stressed and cracks. Laser and EDM cutting methods melt the amorphous material and cause of undesirable crystallisation.
Additionally, these methods make undesirable connection between separated amorphous ribbons in laminated plates, strips and cores.
These connections cause of eddy current and additional losses of energy.

General Electric in 1981 produced electric motor from amorphous material Metglas 2605 CO. The material was cut by chemical method, but the method was found very slow and expensive. [3]

Australian Patent No. 623981 gives method of cutting amorphous materials, on a various shapes, in ambient temperature without cracking, melting and undesirable crystallisation and without connections between separated amorphous ribbons in laminated plates, strips and cores.

Research shown, that during cutting holes in laminated strips, the material is delaminated adjacent to cutting places.

During cutting blend shapes, delamination occurs much easier. The cutting surface became not perpendicular to the surface of the material, after increasing the cutting speed. It was found that the above method is suitable for cutting laminated strips not thicker than 3mm, with lamination factor not exceed 0.825.

In modern electric machines lamination factor have to be as high as possible. Due to little thickness of the singular cut plate, process of cutting and assembling of completed core of the machine is slow. Although the above method allows cutting amorphous material on any profiles without changing its physical structure, the method is not convenient to massive production of electric rotating machines from amorphous materials.

The current invention presents method of cutting laminated amorphous material on thickness even bigger than 18mm and with higher than 0.825 lamination factor. The invented method is based on liquids and abrasive powders claimed with Australian Patent No. 623981.

The above mentioned method of lamination thick cores of amorphous material together with the method of cutting such cores open a new technology of production amorphous magnetic circuits to electric rotating machines.

To assist with understanding this invention, reference will be made to accompanying with the drawings.

1. Preparation the material for cutting.

Stack of cutting material have to be strongly compressed as near as possible to cutting surfaces as shown on figure 2 and on figure 3, (1) - material, (2) clamping tools, (3) - cutting nozzle.

The angle "A" have to be the same or bigger than angle "B" of the cutting nozzle.
The pressing tools are absolutely required during cutting materials with higher than 0.825 lamination factor and during cutting any holes in any laminated amorphous materials, even thickness of materials is below 3mm.

2. Preparation of the cutting machine.

Liquids and abrasive powders have to be as required in Australian Patent 623981.
Figure 4 present: (1) - very hard amorphous material, (2) - soft interlayer adhesive material, (3) - cutting stream with abrasive powder.

During cutting, the high pressure liquid (3) penetrates soft interlayer space of glue (2). To avoid such penetration and delamination of the material a granularity of the abrasive powder shall be as big as possible and in any case should not be smaller than wide of interlayer glue space.

During cutting hard materials, and in particular during cutting non uniform (laminated) hard materials, the cutting surface become not perpendicular to surface of the material. It was found that the flare effect, as shown on figure 5 depends on energy stream density of cutting liquid, hardness and the lamination factor of the material.
Required perpendicularity will remain if the cutting nozzle is big enough and it is set up as near as possible to the cutting material. In any case of cutting laminated amorphous cores, the distance shall not be bigger than 5 to 7mm.

3. Process of cutting.

To avoid any delamination, the process of cutting is started on edge of the material, The starting edges are also edges any holes made in the material by any method. The starting points are presented on figure 6 where (1) - amorphous material, (2) - clamping tools, (3) - cutting nozzle, (4) - starting points.

4. The cutting machine.

4.1. Inclining jet cutting machine.

Lack of perpendicularity mentioned above is also reduced, by incline stream of cutting liquid and/or by incline a base of the cut material as presented on figure 7, (1) - nozzle with cutting jet, (6) rotared base, (2) - the cut material, (5) - cutting angle.
The flare effect (4) is moved on side on wasted material (3). Such inclining of cutting stream, allows perpendicular cutting of thicker laminated cores, using the same energy density of the cutting stream.
Bigger inclining of the cutting jet, allows to cut any required three dimensional profiles in any materials.
Movement of inclining head and/or inclining base is to be controlled by computer program incorporated with main computer program of the cutting machine.

The method was successfully found, using liquid cutting machine, on the cutting of 19mm thick cores, laminated from Metglas ribbons, with required perpendicularity between the cut and the material surfaces as presented on figure 8.

It was also successfully found during cutting cone shape on stator self braked electric machine on 19mm laminated core of Metglas ribbons as shown on figure 9.

4.2 Multi heads machine.

After using too high speed of cutting, lack of required profile occurs on the cutting surfaces.
To intensify the cutting process more than one cutting heads are employed. The heads are supplied by their liquids and abrasive powders. They are controlled by the computer program.

The disclosed cutting method was successfully found, using cutting machine Wizzard 2000, in cutting 19mm thick cores with lamination factor 0.855. Cutting surfaces were perpendicular to the material's surface, very smooth, without any cracking and delamination.
These cores prepared and cut according to the disclosed method were used in prototype production of asynchronous electric motors from amorphous material Metglas 2605 TCA.

Tests of these motors confirmed very high quality of lamination and cutting its magnetic cores.

Other Publications

1. D.M. Nathasingh, H.H. Liberman.
"Transformer Application of Amorphous Alloys in Distribution Systems", IEEE Transaction on Power Delivery, Vol. PWRD - 2, No.3, July 1987.

2. Catalog Metglas Allied Corporation, Parsippany NJ 07054 USA.

3. W.R. Mishler: Test Results on a Low Loss Amorphous Iron Induction Motor. IEEE Transactions on Power Apparatus and Systems, Vol. PAS - 100, No.6 June 1991.

4. Metglas Catalogue, Powercore Strips Data - 1987.

5. S.D. Washko: Origin of Losses in 2.54cm wide Metglas Alloy 2605 SC. J. Appl Phys. 52 (3), March 1981, American Institute of Physics.

6. Catalogue of Magnetic Materials. BHP Australia.

CLAIMS

The claims defining method of production and cutting cores from non crystal, amorphous materials to magnetic circuits of rotating electric machines are as follows:

1. Method of cutting by high pressure liquid of any profiles on magnetic circuits made from non crystal, amorphous magnetic material prepared for using in alternative magnetic field as cores for electric machines, assembled from ribbons, strips or plates by any method, on any thickness, annealed or not, requires using ofnon corrosive cutting liquids and non corrosive abrasive powders.

2. Granularity of abrasive powder, diameter of nozzle, speed of cutting and pressure of liquid, have to be accordingly adjusted to obtain sufficient cutting quality and perpendicularity between cutting surface and surface of the material, in respect of thickness of the cutting material and its lamination factor.
Granularity of the abrasive powder have not to be smaller than wide of interlayer space of the adhesive material. Diameter of nozzle have to be as big as possible in respect to obtain required cut profiles.
The nozzle should be set up as near as possible and no more than 7mm away from surface of the cut material. Liquid pressure have to be of at last 10000 Psi (69000 kPa)

3. During the cutting of profiles in cores of amorphous material with lamination factor higher than 0.8 and during cutting any holes in these materials even lamination factor is lower than 0.8, the cut material has to be strongly compressed as near as possible to such holes and lines of cutting.

4. The cutting lines have to be started from any edge of laminated amorphous core, and/or from any edge of holes in amorphous core.

5. Three dimensional cutting of any inner profiles in the cut material is achieved by incline of the cutting stream. The angle of inclining has to be

appropriate to obtain required profiles and surfaces, and it has to be between -90 and 90 degree.

6. The cutting machine should have employ one or more cutting heads supplied with cutting liquid and abrasive powder work according to the same computer program.

7. An adhesive material used for compacting amorphous ribbons to strips and cores to rotating electric machines have to be in liquid or semi liquid stage in ambient temperature and it have to be cured fast in higher (above 80 and below 180 Celsius Degree) temperature, without production of any gas. The material have to be resistant to the higher temperature as required for annealing of amorphous magnetic materials.

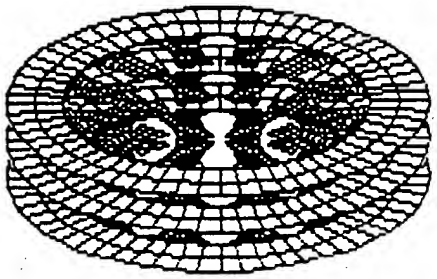

Figure 1a.

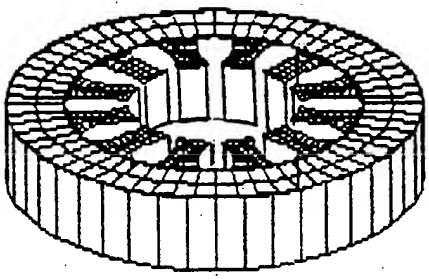

Figure 1b.

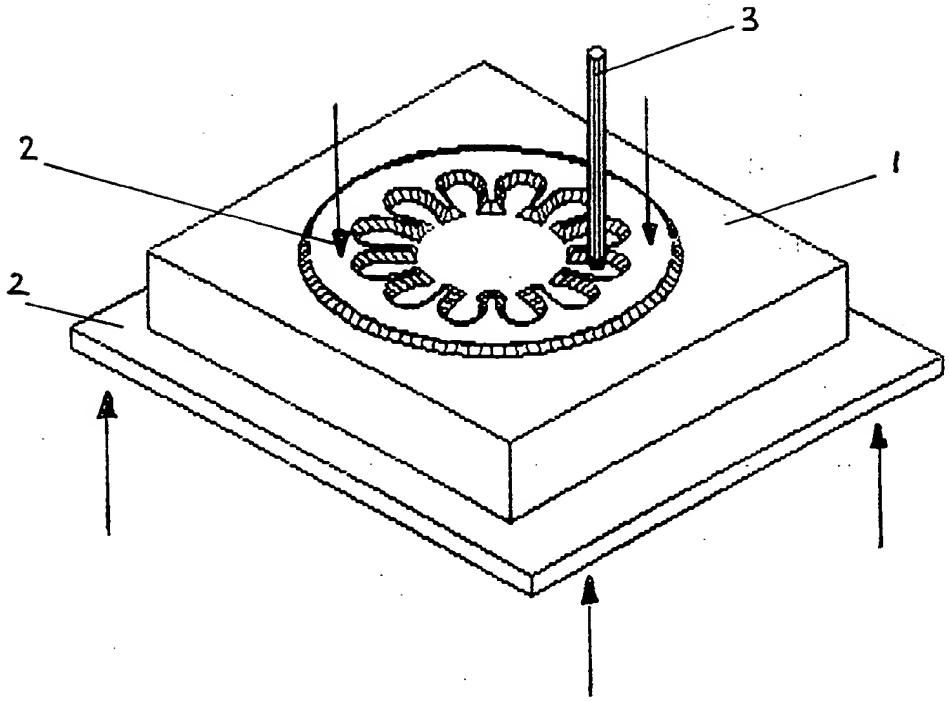

Figure 2.

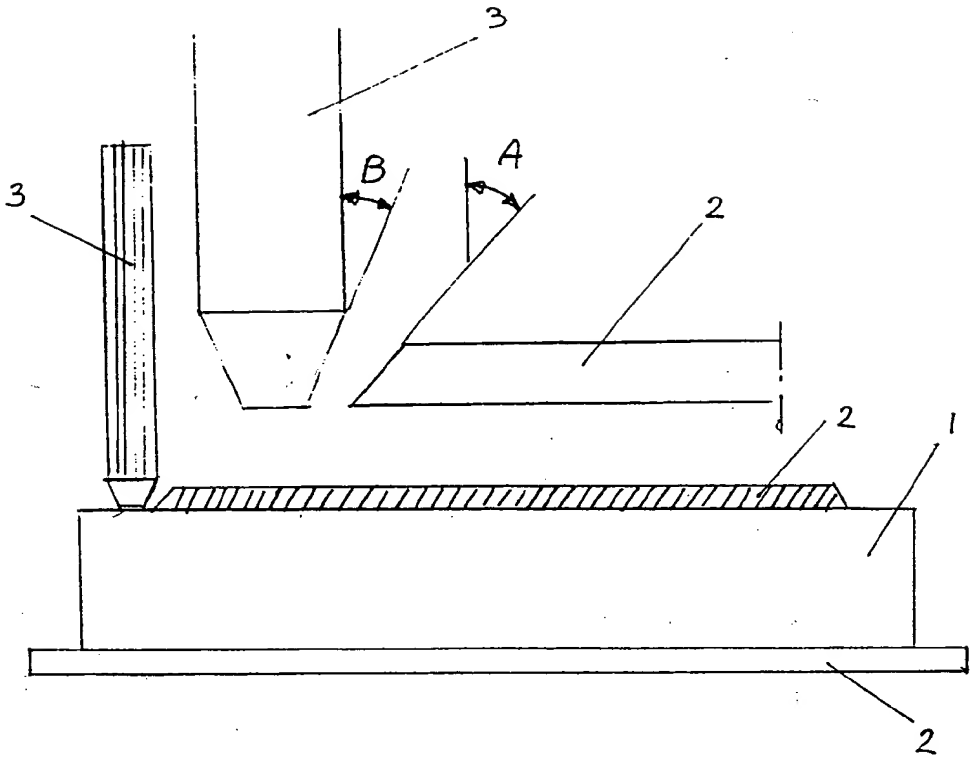

Figure 3.

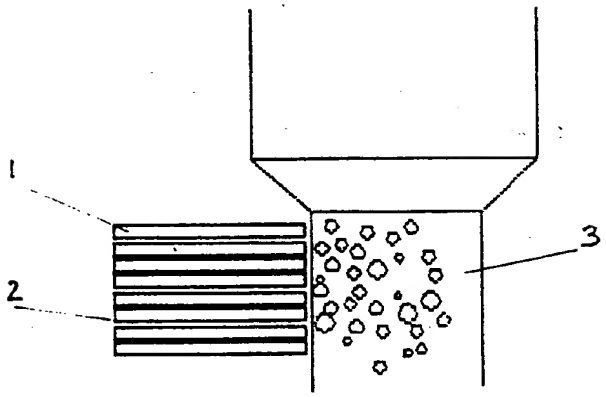

Figure 4.

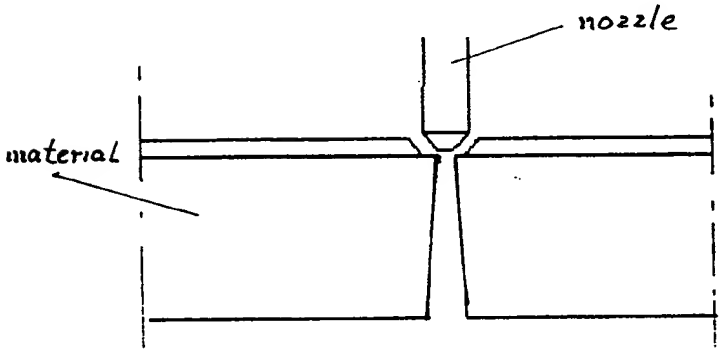

Figure 5.

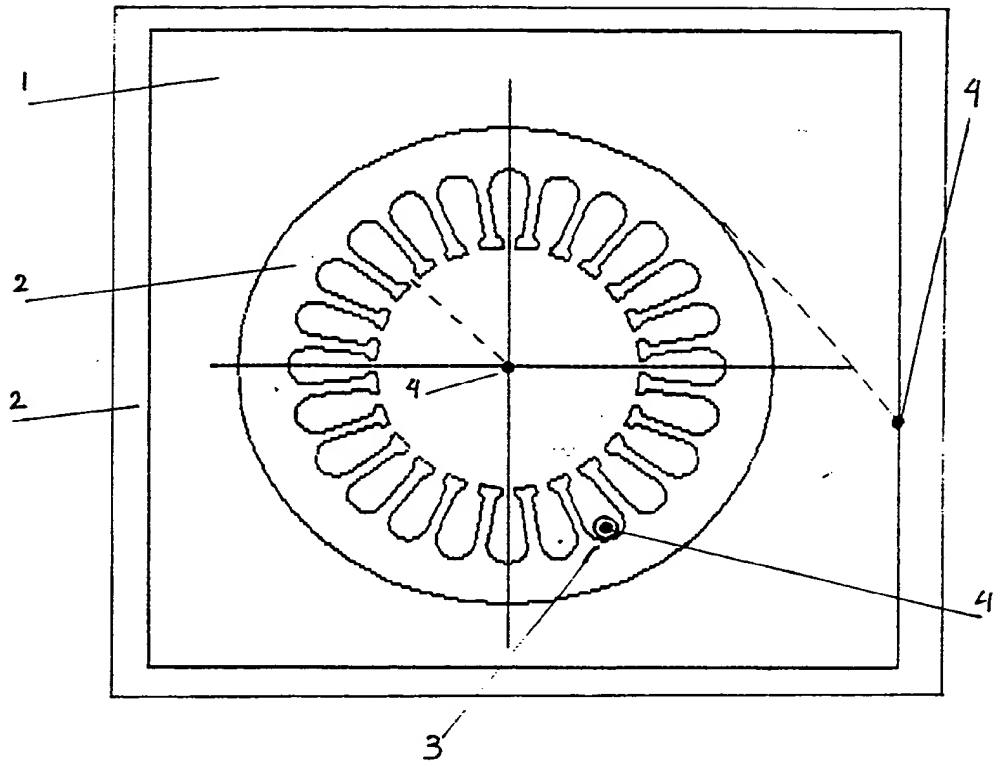

Figure 6

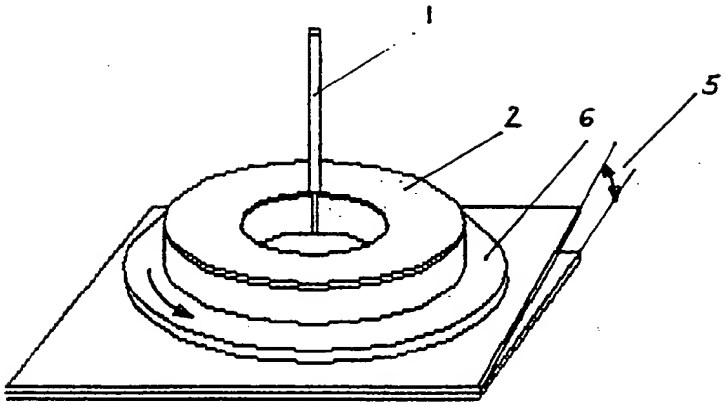

Figure 7a.

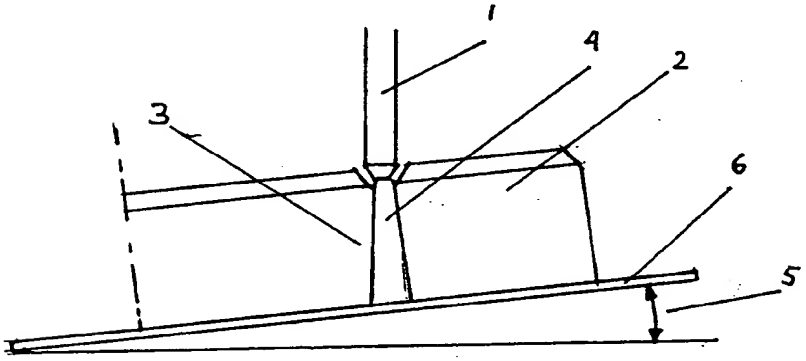

Figure 7b.

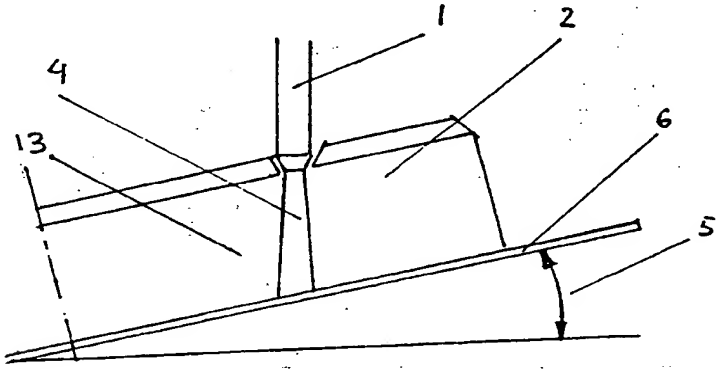

Figure 8.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 95/00048

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl.[6] B24C 1/00 11/00 B26F 1/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC B24C 1/00 11/00 B26F 1/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim N .
X	AU 89668/91 (632981) B (STEC) 14 January 1993 entire document	1-7
A	EP 618041 A (YAMAHARU) 5 October 1994 entire document	2
A	AU 47116/93 A (METSASERLA OY) 17 March 1994 entire document	4
A	US 3526162 A (WILLCOX) 1 September 1970 entire document	6

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 95/00048

Box I **Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)**

This international search report has not established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely: ——

2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II **Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 1-7 are each directed to a different invention, there being no common unifying element of novelty between the claims, - claim 4 defines cutting from an edge, claim 5 defines inclined cutting stream, claim 6 defines more than one cutting head, claim 7 defines abrasive material, claim 3 defines compression during cutting.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically

claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 95/00048

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
AU	89668	WO	9211116
EP	618041	JP	6334086
			END OF ANNEX